V European Conference on Computational Fluid Dynamics
ECCOMAS CFD 2010
J. C. F. Pereira and A. Sequeira (Eds)
Lisbon, Portugal, 14–17 June 2010

IMPORTANCE OF CFD'S ON HVAC

D. Henriques, R. Fernandes

FRANCE-AIR Portugal, av. Casal da Serra Lote I – 4, Escr. 3, 2625-085 Povoa Santa Iria
e-mail: daniel.henriques@franceair.com
e-mail: ricardo.fernandes@franceair.com

Key words: *CFD, comfort, diffusion, velocity, temperature.*

Abstract. *Nowadays, people spend most part of the day inside of buildings. Therefore, it is very important to treat the Indoor Air Quality (QAI) as a basic point for the public health and professional efficiency. There are many variables that affect the ideal conditions of comfort:*

- *speed in the occupied area*
- *invironment temperatures*
- *fresh air ratios*
- *ventilation ratios (DIFFUSION)*
- *pollutants ratios.*

The objectives of the new legislation (RSECE[1] and RCCTE[2]) are clear, defining limits of the air speed in the occupied zone, minimum ratios of fresh air, appropriate values of temperature to each situation and maximum concentrations of pollutants. In complex situations, numerical simulations are suggested in order to obtain the ideal conditions of comfort and QAI. Therefore, numerical simulation CFD is a tool which reveals a significant importance to solve/validate situations out of standard, of difficult resolution or not regulated.

The diffusion of air assumes high importance defining the best comfort and QAI conditions. The right choice of a diffuser, or just the choice of its position in a space, is determinant in the guarantee of comfort and QAI. With numerical simulations, all situations can be tested, allowing to achieve the best solution.

Several studies of comfort have been made in shopping's, restaurants, discotheques and auditoriums with very good results that allows to conclude that numerical simulations are very close to the results verified in real jobs.

---

[1] RSECE – Energetic and climatization systems regulation for buildings.
[2] RCCTE – Characteristics of thermal behavior regulation for buildings.

1 INTRODUCTION

In the last decade, de demand of HVAC systems increased significantly in our country, in response to the increasing of people's life quality and theirs high level of demand in terms of comfort.

Such developments led to the highest growth rate of energy consumption on the building sector. On the other hand, the lack of requirements demands for minimum air change have led to the emergence of problems of indoor air quality, some of which have significant impact on public health [1].

Is in this context that the new legislation fits in (RSECE/QAI), defining thermal and hygienic comfort conditions that should be required on different areas of buildings; improving global energy efficiency of buildings; imposing efficiency rules on climatization systems to improve their effective energy benefits and ensure the maintenance of a good indoor air quality; inspect regularly the climatization maintenance practices as a condition of energy efficiency and indoor air quality.

Computational Fluid Dynamics – CFD – is a helpful tool which reveals a significant importance to solve/validate situations out of standard, of difficult resolution or not regulated. The diffusion of air assumes high importance defining the best comfort and QAI conditions. The right choice of a diffuser, or just the choice of its position in a space, is determinant in the guarantee of comfort and QAI. With numerical simulations, all situations can be tested, allowing to achieve the best solution.

The present work consists of testing the effect of the installation of nozzles with and without swirl in the climatization of a Shopping's Mall.

2 GENERAL CONCEPTS OF AIR DIFFUSION

Air velocity must be inferior than 0,2 m/s in all occupied zones of all new buildings or buildings with new HVAC systems it needs to comply with the regulation RSECE. Higher speeds will cause thermal discomfort.

2.1 Definitions of air rate changes and air renewal rate

Air renewal rate is the fresh air flow introduced in a space, directly from an exterior opening, or diluted in the total air insufflated from an Air Handling Unit (AHU).

Air rate changes represents the total air flow moved inside the climatized area. Includes, for example, the mix of fresh and recirculated air, or air moved just by a simple fan coil.

Air rate changes ensure the effective renewal rate of fresh air to avoid the maximum concentrations of pollutants in the climatized area. It also ensures a good distribution of air so the ventilation system can be efficient and guarantee that the effective fresh air is the desired. It is necessary a good strategy to placing insufflation diffusers and extraction grilles [1].

2.2 RSECE objectives concerning to pollutants

In normal operation the system has to be able to ensure that the values of pollutants are lower than the values shown on Table 1. These values will be measured at various stages.

Table 1

Parameters	Maximum concentration of reference
Airborne particles	0,15 mg/m^3
Carbon dioxide	1800 mg/m^3
Carbon monoxide	12,5 mg/m^3
Ozone	0,2 mg/m^3
Formaldehyde	0,1 mg/m^3
Volatile organic compounds	0,6 mg/m^3
Microorganisms - bacteria	500 UFC/m^3
Microorganisms - fungi	500 UFC/m^3
Legionella	100 UFC/l
Radon	400 Bq/m^3

In order to prevent maximum concentration of pollutants, there are measures to be taken, such as:

? Indoor pollutants: Using dilution methods – minimal air flow; using methods of replacement of the problematic equipment; using methods of removing localized pollution.

? Outdoor pollutants: Using methods of mechanical and chemical removal of pollutants from outside air.

3 MATHEMATICAL MODELS

Flow simulations are performed using the version 3.0.16 of Airpak-ANSYS commercial program [2]. The numerical code is based on the finite-volume method to solve the RANS/URANS equations [3]. The model used in the present study is described in the next section.

3.1 Numerical model

Steady flow is simulated using RANS equations and energy equation. Change in air density is calculated using the ideal gas equation. Coupling between pressure and velocity is solved using the SIMPLE algorithm. Convective terms are discretized by a second order upwind scheme, like turbulence kinetic energy and dissipation rate and energy. Turbulence is simulated using the standard buoyancy-modified version of k-e model, which allows taking in account the buoyancy effects, with the current wall functions. Gravity forces are also calculated. Under-relaxation parameters are 0.3 for the pressure and 0.7 for the momentum.

4 TECHNICAL DATA OF JET NOZZLES

It is advisable to use nozzles to air-condition large spaces where the supply air is to be discharged from the space surrounding walls or from the parapet of a gallery. The supply air jet pattern depends on the jet velocity, the temperature difference between supply air and indoor air, and the discharge angle; in many cases angle can be predetermined. Adjustable nozzles make it possible to adapt the jet discharge angle to the respective operating conditions [4].

4.1 Jet nozzle and twist nozzle

Jet nozzles are recommended where long throws are required while high acoustic requirements are to be met.

Twist nozzles are recommended where small penetration depths are required for the supply air. The built-in twist element spreads out the air jet, thus considerably reducing its penetration depth. It is possible to combine twist nozzles with jet nozzles within one duct system.

Giving due consideration to the design parameters it is possible to supply fresh air to large assembly halls, exhibition halls, airport terminals, shopping centers etc. using jet nozzles and even twist nozzles, in compliance with the comfort requirements.

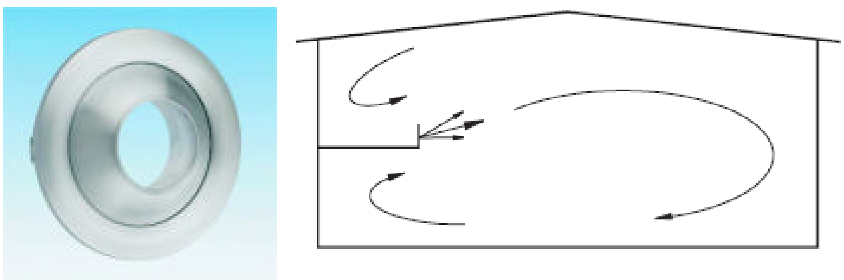

Figure 1: Jet nozzle mounted in the parapet of a gallery.

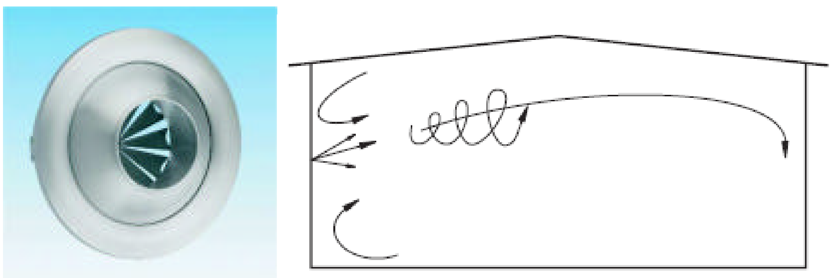

Figure 2: Jet nozzle combined with a twist nozzle, mounted in a wall.

5 APPLICATION OF THE NUMERICAL MODEL TO A SHOPPING'S MALL

CFD is used to verify the efficiency of the diffusion system in the mall of a Shopping. The objective is to verify the levels of comfort (temperature and air velocity) in the occupied zone using nozzles with and without swirl.

In the higher zone, the mall has 11m tall.

58800 m3/h are insufflated by the nozzles. Part of the extraction (15000 m3/h) is made mechanically through a coffee shop, represented on figure 3 by the red circle. The return air (35000 m3/h) passes through one reentrance in an upper level than the nozzles. The remainder flow is extracted on the stores, represented on figure 1 by green's rectangles.

Figure 1 also presents the distribution of the nozzles in the Mall. Nozzles are located 6m above the ground. On the right side of the figure, nozzles have swirl and have no inclination (23 nozzles). On the left, nozzles don't have swirl and are 8º inclined up (34 nozzles). Heat load is distributed on the floor.

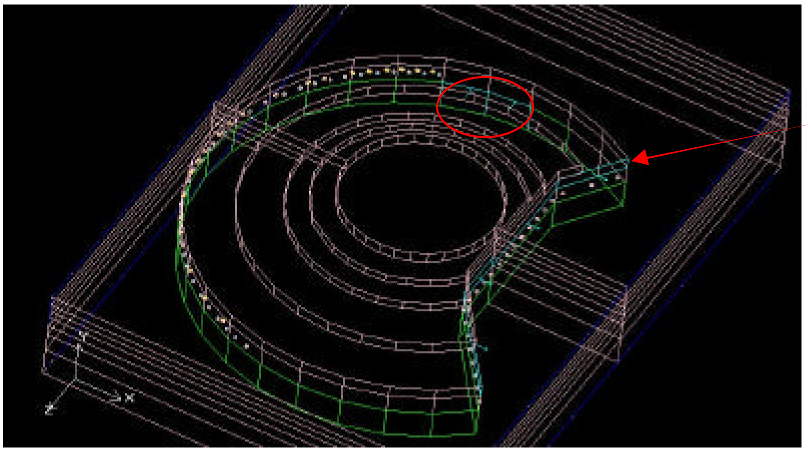

Figure 3: Distribution of the nozzles in the Mall.

Figure 4 presents the mesh well refined, especially on the critical zones (nozzles). The mesh is composed by 1300000 control volumes.

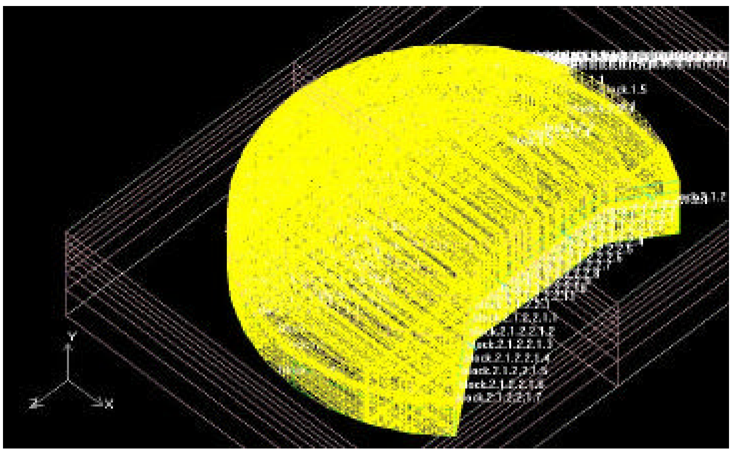

Figure 4: Mesh.

On figures 5 and 6 is represented the difference between the effects of nozzles with and without swirl. On the right side, the nozzle has swirl and 0º of inclination. On the left side, the nozzle has no swirl and is 8º inclined up for a better distribution of air. With no swirl, air reaches a higher distance and has a greater mixing with swirl. Both combined allows acclimate properly all occupied zone.

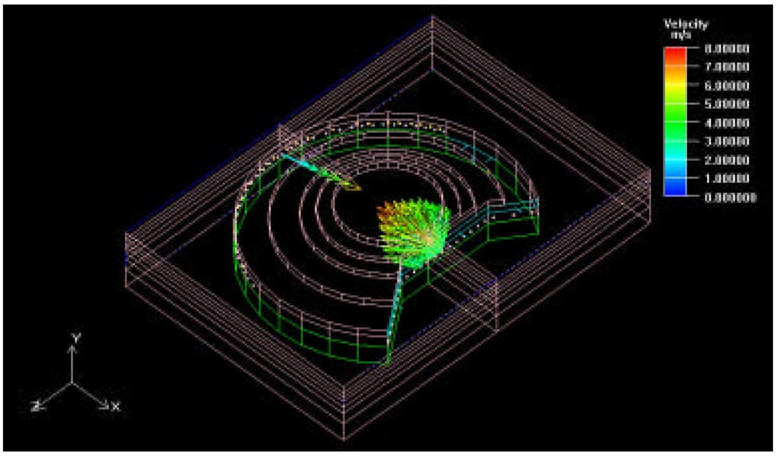

Figure 5: Difference between the effects of nozzles with and without swirl.

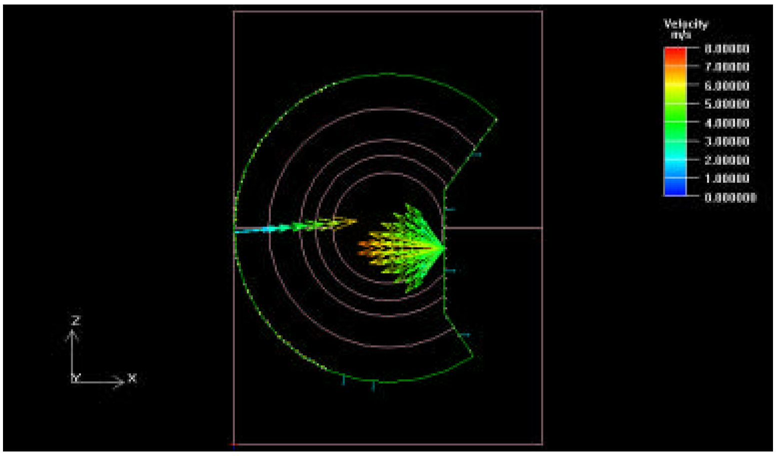

Figure 6: Difference between the effects of nozzles with and without swirl.

Figure 7: Jet dispersion with jet nozzle.

Figure 8: Jet dispersion with twist nozzle.

Figure 7 and 8 serves to compare with figure 6, were the difference between the twist application or not.

5.1 Velocity planes on the occupied zone

Usually, people are seated in this area in a plane lower than 1.8m, so it is not a critical situation when we have velocities higher than 0.2m/s. At this plane people are moving, so it is not an uncomfortable situation.

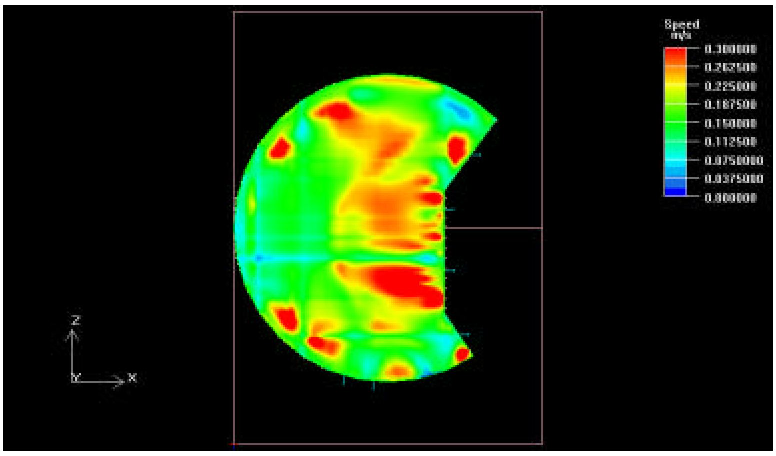

Figure 5: Velocity plane at h=1.8m.

Observing lower planes, 1.2m on figure 6 and 0.8m on figure 7, velocity has values within the parameters of comfort (under 0.2m/s) – the red zones in figure 6 are not critical, since they are circulation zones.

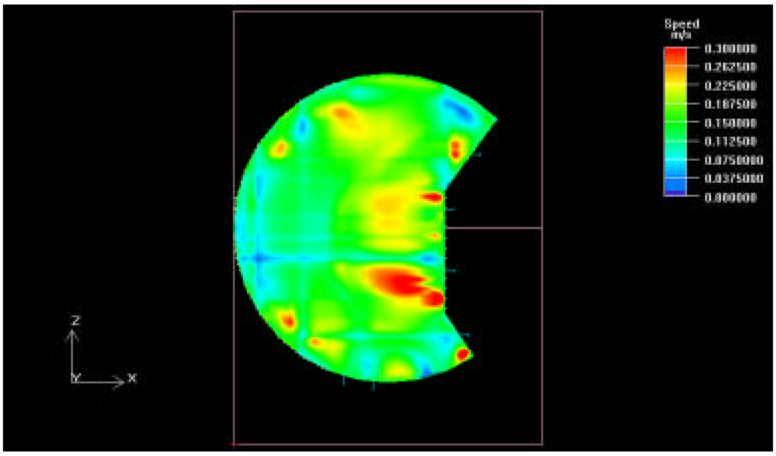

Figure 6: Velocity plane at h=1.2m.

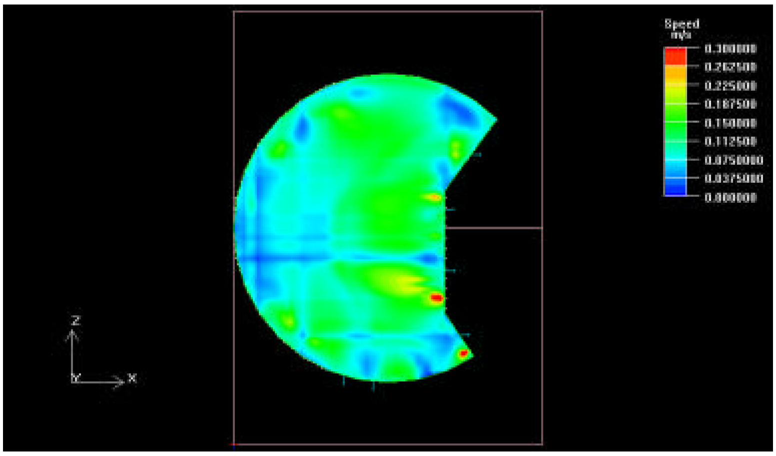

Figure 7: Velocity plane at h=0.8m.

5.2 Temperature planes on the occupied zone

Air is insufflated at 16ºC. As shown on figures 8 and 9, there aren't critical zones of high temperatures. The orange zone represents the area of higher temperatures, never reaching 25ºC.

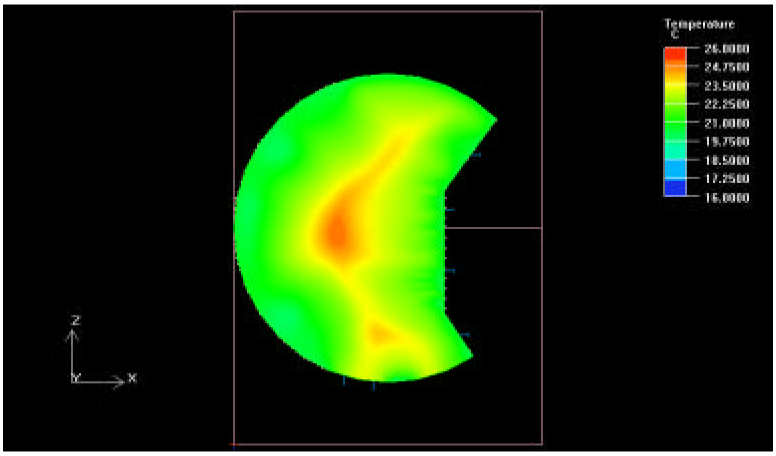

Figure 8: Temperature plane at h=1.8m.

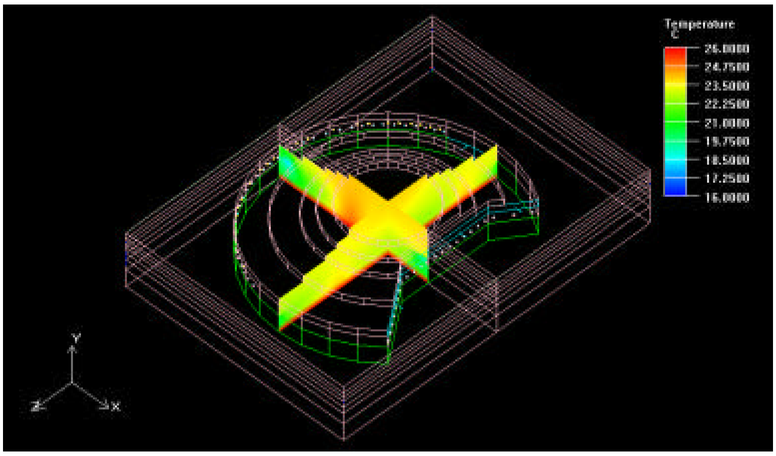

Figure 9: Temperature.

5.3 Mean Age of air planes on the occupied zone

Air is well distributed as shown on figure 9. Mean Age of air represents the average time that air spends in the same place till the extraction. It gives an indication of the wellness of air.

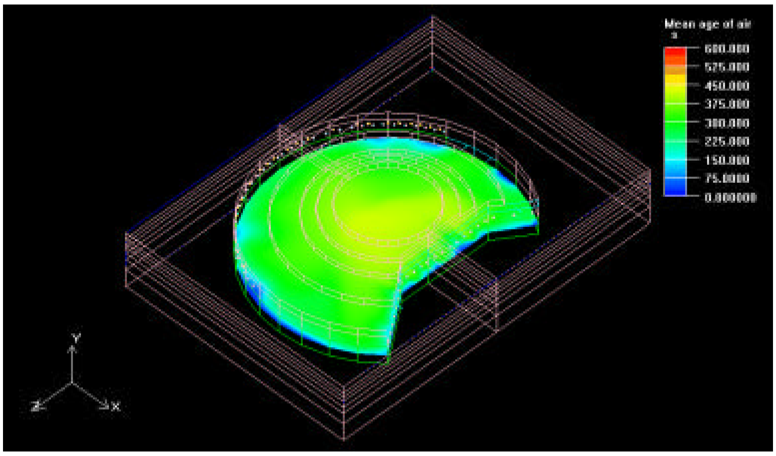

Figure 9: Mean Age of air plane at h=1.8m.

The orange zones on figure 10 are not critical zones because are located in an upper level, that corresponds to the return air area.

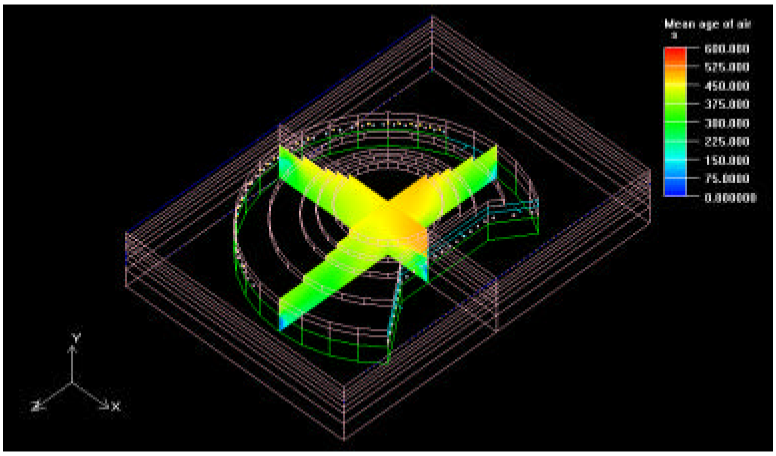

Figure 10: Mean Age of air.

6 CONCLUSION

Computational Fluid Dynamics is a helpful tool to predict the expected flow patterns and to verify the efficiency of the diffusion system. This simulation allows to conclude the best position of the nozzles in the Mall, with the best inclination angle.

Velocity and temperature values are within the parameters predicted in legislation. The combination of jet nozzles with twist nozzles in opposite sides of the mall allows to have good levels of comfort on the occupied zones.

REFERENCES

[1] RSECE, Regulamento de Sistemas Energéticos e Climatização de Edifícios, decreto-lei 79/2006.

[2] J.H. Ferziger and M. Peric, Computational Methods for Fluid Dynamics, New York, Barcelona, Hong Kong, London, Milan, Paris, Singapore, pp. 277-289 (1999)

[3] FLUENT 6.2 User´s Guide, Fluent Incorporated, (2005)

[4] KRANTZ Komponenten, Applied system solutions.